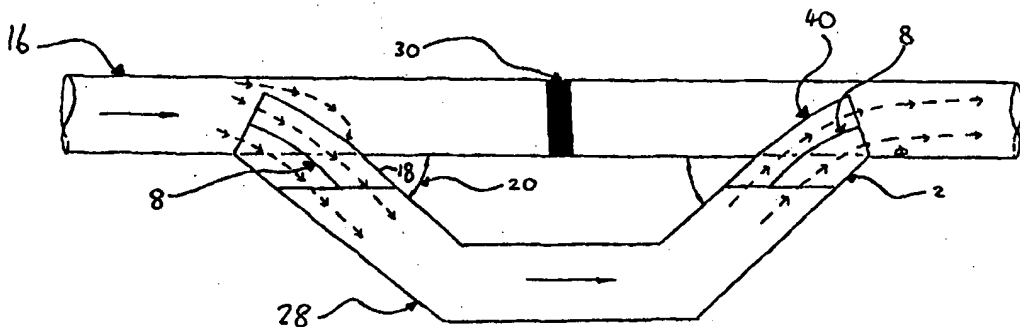




INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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<p>(21) International Application Number: PCT/GB98/01006 (22) International Filing Date: 6 April 1998 (06.04.98) (30) Priority Data: 9706965.2 5 April 1997 (05.04.97) GB (71) Applicant (for all designated States except US): THE QUEEN'S UNIVERSITY OF BELFAST [GB/GB]; 8 Malone Road, Belfast BT9 5BN (GB). (72) Inventor; and (75) Inventor/Applicant (for US only): GILLAN, Mark [GB/GB]; 46 Church Road, Ballynahinch, County Down BT24 8LP (GB). (74) Agent: MURGITROYD & COMPANY; 373 Scotland Street, Glasgow G5 8QA (GB).</p>		<p>(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, GW, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BI, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).</p> <p>Published With international search report.</p>
<p>(54) Title: HAEMODYNAMIC CONTROL DEVICE</p>  <p>(57) Abstract</p> <p>The present invention provides a graft haemodynamic control device suitable for reducing anastomotic intimal hyperplasia, comprising a cylindrical body, optionally with control vanes therein, which connects an artery to a bypass graft and which controls the flow of blood therebetween. The device is made of any compliant material, usually a plastic material such as PTFE, Dacron or Goretex and coated with Teflon. The device is less compliant than the graft. It may be attached to the artery and the graft by recognised techniques.</p>		

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1 **"Haemodynamic Control Device"**

2

3 The invention relates to the surgical procedure of
4 using biological or synthetic grafts to bypass occluded
5 or severely stenosed arteries. Intimal hyperplasia in
6 the vicinity of the vascular anastomoses is a primary
7 factor in the medium and long-term failure of grafts.
8 This invention is a haemodynamic control device which
9 judiciously adapts the local flow field, by reducing
10 both the spatial shear stress gradients and the extent
11 of long particle residence times in the vicinity of an
12 anastomosis, thereby reducing the likelihood of intimal
13 hyperplasia and the subsequent failure of the graft.

14

15 In this field it is already known that

16

17 1. Anastomotic intimal hyperplasia is a common cause
18 of post-operative vascular graft failure,
19 especially for synthetic grafts.

20

21 2. In addition to graft/artery compliance mismatch
22 the other primary mechanism which is universally
23 acknowledged to promote intimal hyperplasia is
24 adverse haemodynamic flow patterns in the vicinity
25 of the anastomosis.

- 1 3. The most common regions exhibiting intimal
2 hyperplasia are around the suture line, at the
3 heel and toe of the anastomosis and along the
4 floor opposite the anastomosis (see Figure 3).
5
 - 6 4. Development of intimal hyperplasia is more
7 prevalent at the distal anastomosis than at the
8 proximal anastomosis.
9
 - 10 5. There is a direct relationship between the
11 localities of intimal hyperplasia and the
12 anastomotic surface which are experiencing low
13 shear and long particle residence times.
14
 - 15 6. High spatial wall shear stress gradients promote
16 intimal hyperplasia.
17
 - 18 7. The anastomotic graft angle is of fundamental
19 importance to defining the wall shear stress: a
20 shallow or small anastomotic angle results in a
21 decreased region of separated flow which reduces
22 the likelihood of intimal hyperplasia.
23
 - 24 8. The anastomotic angle is limited both by the graft
25 material and the mechanics of suturing/skill of
26 the surgeon.
27
- 28 The types of vascular patients that the surgeons treat
29 fall principally into three groups:
30
- 31 **Group 1 - Normal Vascular Patients:**
32
- 33 Typically these patients have atherosclerosis, viz a
34 disease process affecting the wall of arteries and in
35 this group it involves the main arteries of the tummy
36 and thigh extending to about knee level. Essentially

1 this is a process in which yellow fatty plaques build
2 up eccentrically in the arterial wall in different
3 locations. This proceeds at a rate depending on
4 certain critical stimuli, to cause occlusion of the
5 artery. As the plaque develops a varying degree of
6 calcium forms in it causing a varying degree of
7 hardness producing a softish thick walled artery to an
8 artery which will not accept a needle.

9
10 The plaque undergoes a degree of necrosis and blood
11 then clots on it causing complete occlusion, this is a
12 thrombus and it propagates proximally i.e. upstream to
13 the next main branch of the vessel where it stops. The
14 vessels of the calf are only ever mildly affected.

15
16 **Group 2 - The Diabetic Vascular Patient:**

17
18 This patient often has a degree of disease distribution
19 as described above though usually the thigh artery is
20 affected. However this group has the disease always in
21 the three vessels of the calf, the tibial arteries and
22 they are in parallel. They may be hard but principally
23 have concentric layers of atheroma building to cause
24 skip like areas of narrowing and occlusion. Even these
25 are amenable to bypass. But in the diabetic the real
26 problem are the arterioles, the tiny little vessels
27 that bleed when you cut yourself shaving. These are
28 narrowed by the building up of hyaline, a tough scar
29 like material. Again the arterioles are considered to
30 be in parallel hence further increase in peripheral
31 resistance.

32
33 **Group 3 - The Renal Vascular Patient:**

34
35 The kidney patient relies frequently on dialysis and is
36 often Diabetic. This group tends to have a very poor

1 prognosis for in addition to the common features of the
2 Group's 1 and 2 their vessels are remarkably hard even
3 early in life. On the other hand the wall may be very
4 soft but mushy and thick. Their prognosis is
5 determined too by the state of the arterioles and as
6 yet unrecognised biochemical abnormalities relating to
7 the primary renal pathology.

8
9 There is also an interesting but relatively rare group
10 of patients who suffer from thrombophilia which is
11 essentially the opposite of haemophilia where the
12 patient has a disorder of the haemopoietic system in
13 which there is a tendency for thrombosis to occur.

14
15 Currently all present research into this field appears
16 to be cited around optimising the graft material and
17 not controlling the flow at the anastomoses.

18
19 However, this has the disadvantage that, without
20 haemodynamic control at the distal, and to a lesser
21 extent at the proximal anastomosis one will always
22 incur high spatial shear stress gradients in the
23 vicinity of the anastomotic junction and therefore
24 intimal hyperplasia.

25
26 In the medium to long-term, the graft will eventually
27 fail, thus necessitating a new surgical bypass
28 procedure with all the additional risks which it
29 entails.

30
31 According to the present invention there is provided a
32 graft haemodynamic control device suitable for reducing
33 anastomotic intimal hyperplasia, the device comprising
34 a substantially cylindrical body wherein one end is
35 capable of being attached to a bypass graft and the
36 other end capable of being positioned in an artery such

1 that the device connects the graft and the artery and
2 controls the flow of blood there between.

3

4 The device may be manufactured from the same compliant
5 material as the graft but will be less compliant.

6

7 The device may be of one piece construction.

8

9 The device may be manufactured in a variety of sizes
10 and options to match the chosen graft/host artery's
11 architecture.

12

13 In one embodiment the device is configured to be a
14 proximal control device controlling flow from an artery
15 to a graft.

16

17 In an alternative embodiment the device is configured
18 to be a distal control device to control flow of blood
19 from graft into artery.

20

21 The invention may further comprise a kit including
22 proximal and distal haemodynamic control devices.

23

24 In one embodiment the device comprises at least one
25 control vane such that flow is directed between the
26 artery and graft to decrease spatial shear stress
27 gradients and long particle residence times in the
28 vicinity of anastomoses.

29

30 More preferably the device comprises at least one
31 control valve such that flow is directed between the
32 artery and graft to decrease spatial shear stress
33 gradients when used in larger diameter host arteries.
34 Larger diameter host arteries are defined as having a
35 bore of greater than 6 mm.

36

1 In one embodiment the control vane divides the body of
2 the device into two separate chambers.

3

4 Suitably the device may be manufactured from any
5 compliant material.

6

7 Preferably the device is coated with teflon or a
8 similar material.

9

10 Preferably also the device is manufactured from any one
11 or any mixture of the group consisting of PTFE, Dacron
12 or Goretex.

13

14 Suitably the device may be attached to grafts using
15 established methodology such as suturing or biological
16 glues.

17

18 The shape and dimensions of the device will differ
19 depending on the size of the host artery and graft and
20 on whether it is to be attached at the proximal or
21 distal ends of the graft.

22

23 In a preferred embodiment the device comprises a
24 peripheral collector, which may comprise a thin
25 compliant porous area, to enhance flow vectoring into
26 the graft.

27

28 The invention can further comprise a peripheral
29 ejector, which may comprise a thin compliant porous
30 area, in the device to enhance flow vectoring into the
31 host artery.

32

33 Suitably the device can further comprise secondary
34 control vanes to enhance flow vectoring into and out of
35 larger diameter grafts.

36

1 Most preferably the device can further comprise
2 secondary control vanes to enhance flow vectoring into
3 and out of larger diameter grafts (diameters greater
4 than 1 cm).

5

6 The diameter of the device according to the invention
7 can range from 2mm to 1.5cm depending on the size of
8 the grafts and the host arteries being connected.

9

10 Typically a device according to the present invention
11 is of a synthetic one-piece construction and
12 incorporates a primary control vane and a periphery
13 collector or ejector.

14

15 The device may include constant angle guidelines to
16 assist attachment to the graft at optimum anastomotic
17 angle.

18

19 The invention further provides a kit comprising a
20 synthetic graft and proximal and distal haemodynamic
21 control devices.

22

23 Suitably one end is unattached to allow the other end
24 to be cut to size.

25

26 The invention also provides preattached or integral
27 haemodynamic control devices on synthetic grafts.

28

29 The present invention will now be further described by
30 way of example with reference to the accompanying
31 drawings, in which:

32

33 Figure 1 is a front view of the haemodynamic flow
34 control device, taken along a cross section, showing a
35 schematic enlargement of a haemodynamic control device
36 for proximal side-to-end anastomosis.

1 Figure 2 is a front view of the haemodynamic flow
2 control device of Fig. 1, taken along a cross section,
3 showing the schematic haemodynamic flow pattern for an
4 occluded bypass graft with the haemodynamic flow
5 control device of the present invention fitted at both
6 the proximal and distal anastomoses;

7
8 Figure 3 shows the schematic haemodynamic flow pattern
9 for an occluded bypass graft with regions of intimal
10 hyperplasia in the vicinity of the distal end-to-side
11 anastomosis;

12
13 The haemodynamic flow control device as shown in
14 Figures 1 and 2 is formed from a single piece of
15 plastic material 2, which is shaped to form a
16 cylindrical body 4. The bore 6 of cylindrical body 4
17 is divided into two by control vane 8 and is further
18 divided into four by parallel secondary control vanes
19 10 and 12. Control vanes 8, 10 and 12 run along the
20 longitudinal axis of cylindrical body 4. The rim 14 of
21 cylindrical body 4, designed to be sutured into the
22 host artery 16 has an overlap flap 18 running the
23 outside of the cylindrical body 4 at anastomotic angle
24 20 from one edge of the rim 14. The area of the
25 cylindrical body 4, above the overlap flap 18 is
26 porous. Also running around the edge of the
27 cylindrical body 4 at the end designed to be attached
28 to the graft and at the anastomotic angle 20, are a
29 series of incisions 22, 24 and 26 spaced equidistantly,
30 as graft attachment guidelines (synthetic grafts only).

31
32 In use the haemodynamic flow device (2) is attached to
33 host artery 16 at anastomotic angle 20 by virtue of
34 overlap flap 18, by conventional methods and is
35 attached to graft 28 in order to bypass occlusion 30.
36 Use of the flow control device helps to prevent effects

1 shown in figure 3 such as undesirable flow effects 32
2 and 34 and helps to prevent intimal hyperplasia build
3 ups 36, 38 and 40.

4
5 This invention is a novel vascular graft haemodynamic
6 control device (HCD) which can be attached at either,
7 or both, the proximal and distal anastomotic junctions.
8 The HCD judiciously adapts the local flow field, by
9 decreasing both the spatial shear stress gradients and
10 the extent of long particle residence times in the
11 vicinity of an anastomosis, thereby reducing the
12 likelihood of intimal hyperplasia and the subsequent
13 long-term failure of the graft.

14 15 HCD Design

16
17 The HCD is of a synthetic one-piece construction and
18 can optionally incorporate a primary control vane (8)
19 with optional secondary control vanes (10,12) and an
20 optional periphery collector/ejector. Fig 2 shows a
21 typical vascular bypass graft with two HCD's attached
22 at both the proximal and distal anastomoses. Both of
23 the HCD's depicted in Fig 2 contain a primary control
24 vane and the optional periphery collector/ejector. The
25 HCD is manufactured in a variety of sizes and options
26 to match the chosen graft/host arteries' architecture.

27 28 Primary Control Vane

29
30 The primary control vane (8) (see Fig 1) is a thin
31 compliant haemodynamic flow vectoring control surface.
32 The length, axial location and variable pitch of the
33 primary control vane is optimised for the HCD size,
34 locality (i.e. proximal or distal) and the elasticity
35 of the host artery.

36

1 Optional Secondary Control Vanes

2

3 The optional secondary control vanes (10,12) (see Fig
4 1) are thin compliant haemodynamic flow control
5 surfaces which are utilised to enhance flow vectoring
6 into and out of the larger diameter grafts. The
7 length, axial location and variable pitch of these
8 control vanes are once again optimised for the HCD
9 size, locality (i.e. proximal or distal) and elasticity
10 of the host artery.

11

12 Optional Periphery Collector/Ejector

13

14 The optional periphery collector/ejector (40) (see Fig
15 2) is a thin compliant porous haemodynamic collector or
16 ejector device depending on whether the HCD is at the
17 proximal or distal anastomosis respectively. The
18 length, porosity and variable pitch of the periphery
19 collector/ejector is dependant on the primary control
20 vane dimensions, the locality (i.e. proximal or distal)
21 and elasticity of the host artery. The periphery
22 collector/ejector is utilised to enhance flow vectoring
23 and to reduce the extent of long particle residence
24 times fore and aft of the occlusion.

25

26 Surgical HCD Attachment Procedure

27

28 The HCD may be attached (during the surgical procedure)
29 to existing synthetic or biological grafts using a
30 variety of established methodologies, including
31 suturing and biological glues. The HCD is attached to
32 the graft in a manner which allows a small overlap of
33- graft material to remain above the attachment point
34 thereby enabling the surgeon to suture and/or bond the
35 graft onto the artery as normal (see Fig 2). As
36 depicted in Fig 2 the HCD synthetic graft attachment

1 procedure can be made more straightforward by the
2 addition of constant angle guide-lines (22,24,26) along
3 the length of the graft thus ensuring that the surgeon
4 attaches the graft and HCD at the optimum anastomotic
5 angle. (Note: pre-attached (or integral) HCDs on the
6 proximal end of synthetic grafts can be employed to
7 simplify/expedite some of the more uncomplicated
8 surgical bypass procedures).

9
10 The advantages of the invention and/or the ways in
11 which the disadvantages of previously known
12 arrangements are overcome, include:

13

14 Procedural:

15

16 1. The haemodynamic control device judiciously adapts
17 both the proximal and distal anastomotic graft
18 flow-patterns thereby reducing both local spatial
19 shear stress gradients and the extent of long
20 particle residence times thus decreasing the
21 likelihood of intimal hyperplasia in the
22 vicinities of the heel, toe and floor regions
23 (see Fig 3).

24

25 2. The associated increase in the medium to long-term
26 patency of the graft anastomoses enhances the
27 patient's survival rate.

28

29 3. The graft/control device attachment procedure is
30 relatively straightforward and the associated
31 synthetic graft suturing guide-lines ensure that
32 the surgeon attaches the graft at the optimum
33 anastomotic angle.

34

35 4. The control device may also be utilised in
36 biological grafts.

1 Fiscal:

2

3 1. The control device can be attached to existing
4 grafts.

5

6 2. Enhanced medium to long-term patency reduces the
7 need to perform expensive staff intensive re-
8 operative procedures which are statistically less
9 successful than the original procedure.

10

11

1 **Claims**

2

3 1. A haemodynamic control device suitable for
4 reducing anastomotic intimal hyperplasia, the
5 device comprising a substantially cylindrical body
6 wherein one end is capable of being attached to a
7 bypass graft and the other end capable of being
8 positioned in an artery such that the device
9 connects the graft on the artery and controls the
10 flow of blood there between.

11

12 2. A haemodynamic control device as claimed in Claim
13 1, which is configured to be a proximal control
14 device controlling flow from an artery to a graft.

15

16 3. A haemodynamic control device as claimed in Claims
17 1 or 2 which is configured to be a distal control
18 device to control flow of blood from graft into
19 artery.

20

21 4. A haemodynamic control device as claimed in Claims
22 1, 2 or 3, which comprises a least one
23 longitudinal control vane.

24

25 5. A haemodynamic control device as claimed in Claim
26 4 wherein the control vane divides the body of the
27 device into two separate chambers.

28

29 6. A haemodynamic control device as claimed in any
30 preceding Claim which is manufactured from a
31 compliant material.

32

33 7. A graft haemodynamic control device as claimed in
34 Claim 6 wherein the compliant material is less
35 compliant than the material of the graft.

36

- 1 8. A haemodynamic control device as claimed in any
2 preceding Claim, which is manufactured from any
3 one or any mixture of the group consisting of
4 PTFE, Dacron or Goretex.
5
- 6 9. A haemodynamic control device as claimed in any
7 preceding Claim which is coated with a Teflon type
8 material.
9
- 10 10. A haemodynamic control device as claimed in any
11 preceding Claim, which is attachable to grafts
12 using established methodology such as suturing or
13 biological glues.
14
- 15 11. A haemodynamic control device as claimed in any of
16 Claims 1, 2 and 4 to 10 comprising a peripheral
17 collector, which may comprise a thin compliant
18 porous area, to enhance flow vectoring into the
19 graft.
20
- 21 12. A haemodynamic control device as claimed in any of
22 Claims 1 and 3 to 10 which further comprises a
23 peripherally ejector, which may comprise a thin
24 compliant porous area, in the device to enhance
25 flow vectoring into the host artery.
26
- 27 13. A haemodynamic control device as claimed in any
28 preceding Claim which further comprises secondary
29 control vanes to enhance flow vectoring into or
30 out of an outer large diameter graft.
31
- 32 14. A kit comprising at least one proximal
33 haemodynamic control device and at least one
34 distal haemodynamic control device.
35
- 36 15. A synthetic graft including a haemodynamic control

- 1 device as claimed in any of the preceding Claims.
- 2
- 3

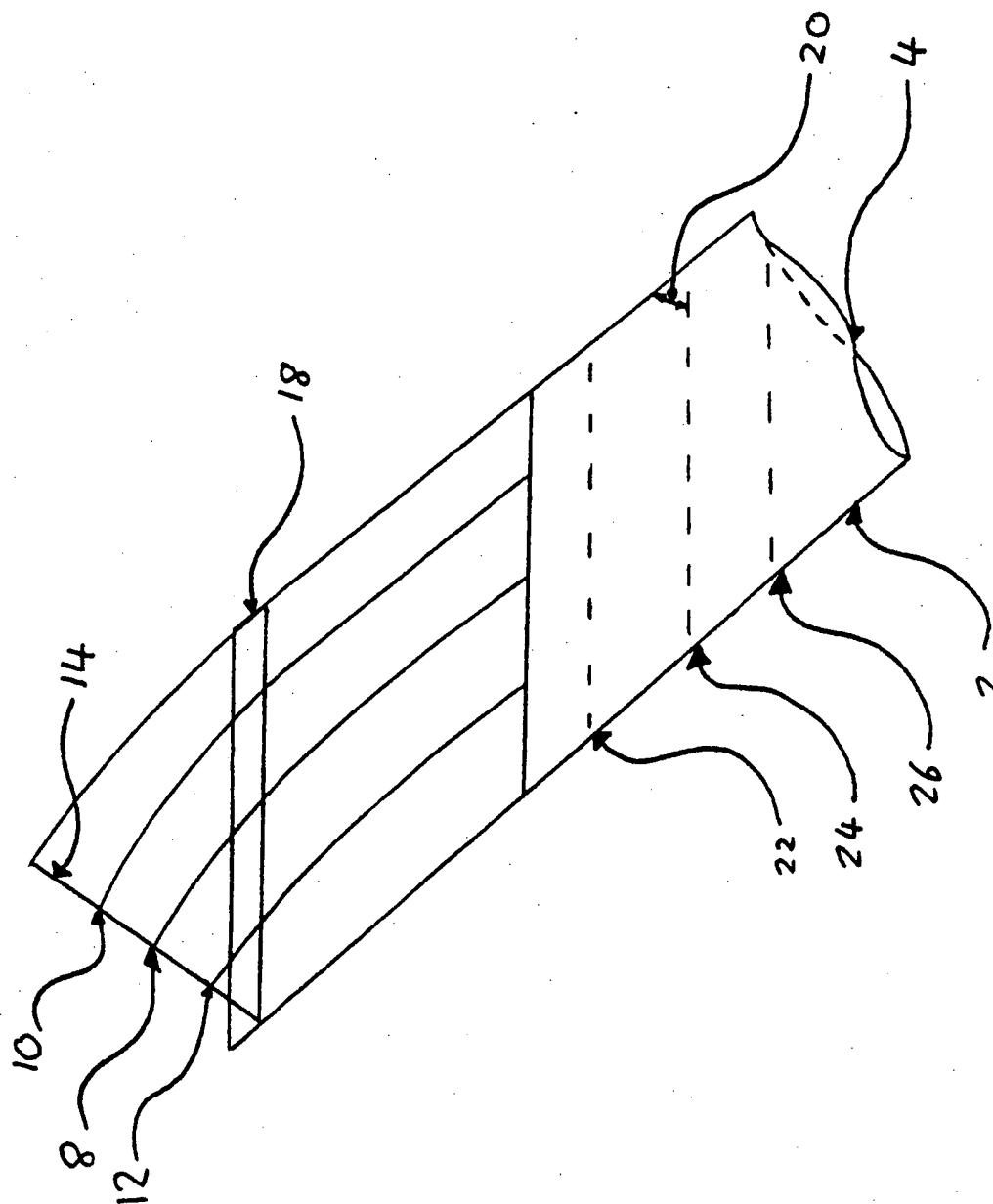


Figure 1
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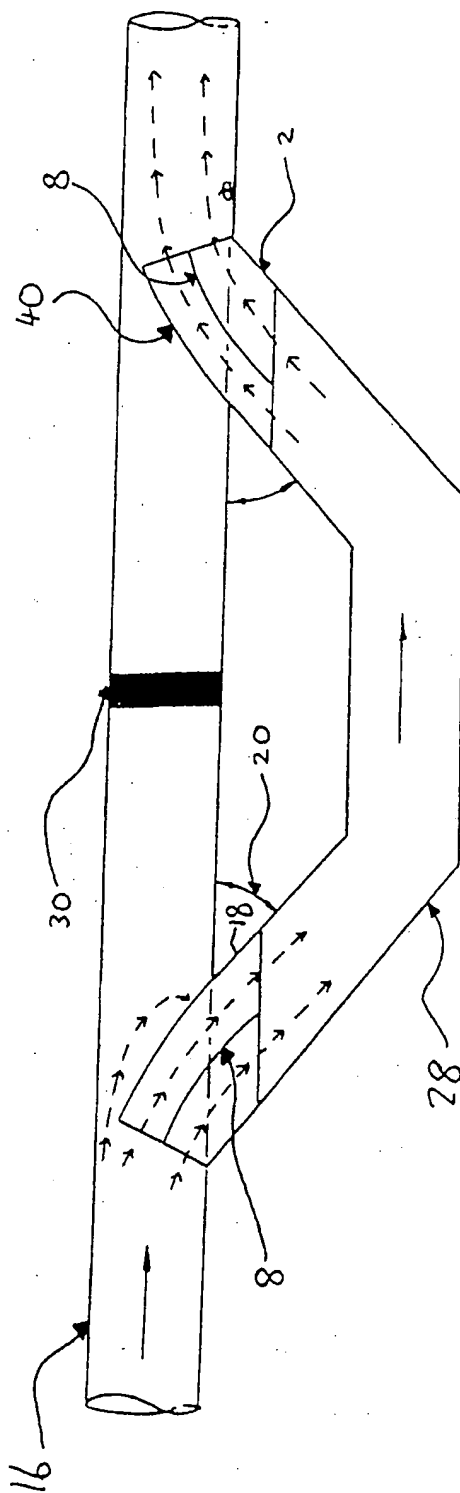


Figure 2
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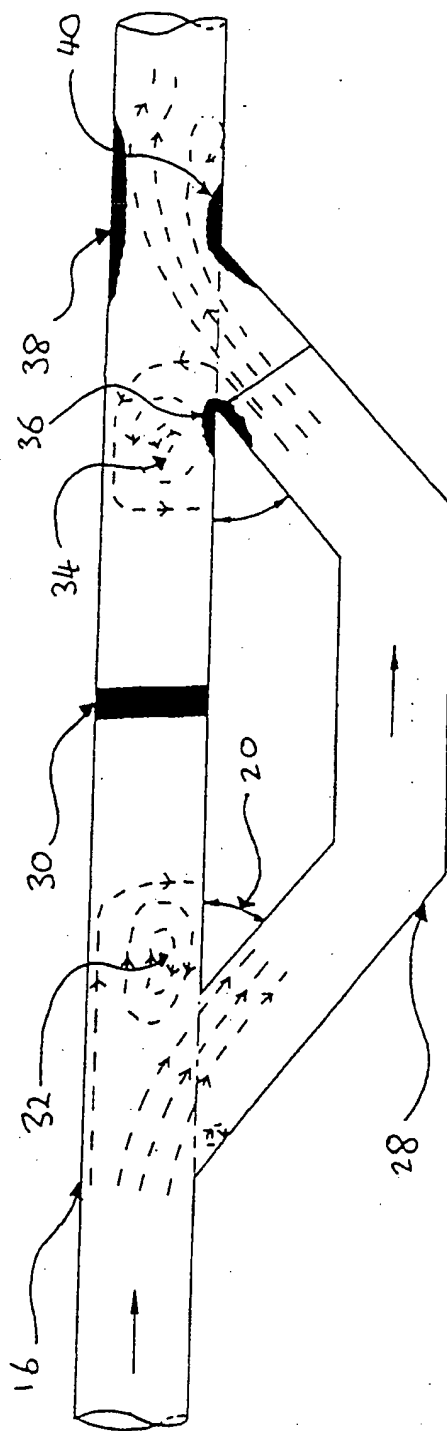


Figure 3
3/3

INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 98/01006

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 A61F2/06 A61B17/11

According to International Patent Classification(IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 A61F A61B A61M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 503 568 A (MADRAS) 12 March 1985 see the whole document ---	1, 14, 15
A	US 3 882 862 A (BEREND) 13 May 1975 ---	
A	US 3 818 511 A (GOLDBERG ET AL) 25 June 1974 -----	

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Date of the actual completion of the international search

13 July 1998

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INTERNATIONAL SEARCH REPORT

information on patent family members

International Application No

PCT/GB 98/01006

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4503568 A	12-03-1985	NONE	
US 3882862 A	13-05-1975	NONE	
US 3818511 A	25-06-1974	NONE	

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